AN ECOLOGICAL STUDY OF THE WORM PARASITES OF PORTAGE LAKES FISHES

ROBERT C. HARE
University of Akron, Akron, Ohio

During the years of 1939 and 1940 a taxonomic and ecological study was made of the worm parasites of the fishes of the Portage Lakes, near Akron, Ohio. The complete results of this work are presented in an unpublished thesis (Hare, 1941) of which the present paper is a summary.[1]

We have attempted to bring out in this work not only the kinds of worms found in each host, but also to show the various ecological factors involved, e.g., the effect of season, habitat, age, and food relations on parasitism.

The Portage Lakes comprise a chain of small lakes and reservoirs extending southward from the city of Akron, Ohio. Summit Lake is within the city. Nesmith Lake, 41 acres, depth 10–24 feet; North Reservoir, 136 acres, depth 4–12 feet; East Reservoir, 292 acres, depth 12–25 feet; and Turkeyfoot Lake, 531 acres, depth 10–50 feet, were the principal lakes from which collections were made. The group includes also Long Lake, West Reservoir, and smaller tributary lakes as Hower's Lake from North Reservoir, Mud Lake and Rex Lake from Turkeyfoot. There is also small, shallow, weedy Grape Lake. Further to the south is the still larger, newly formed Nimisila Reservoir. A few specimens were also taken from the Ohio Canal, part of which connects Summit Lake with Nesmith Lake. The shore line of the chain offers a great variety of conditions from cottage-lined banks to large marshy areas. The lakes and fish conditions were reported on by Osburn (1921), and studies of fish food and plankton were made by Kraatz (1928, 1931, 1941).

Acknowledgment of indebtedness of the author goes to Paul Eschmeyer for collections of fish and their identification; Dr. R. V. Bangham for identification of many parasites; Fred H. Glenny for assistance in preparing slides of parasites; Samuel Caplin for photographs of parasites (not included in this paper), and Dr. Walter C. Kraatz for suggestions and help in the work and the thesis and this paper.

COLLECTIONS AND PREPARATION

Fish were caught over a period of a year by set net, seine, and hook and line from all possible ecological habitats and examined fresh immediately or after icing.

All worm parasites were removed while alive and kept for study in a 0.7% $NaHCO_3$ solution (Van Cleave and Mueller, 1934). Fish were examined singly by hand; each organ removed to separate dish of soda solution; parasites removed and freed of mucus in fresh solution.

Several killing and fixing agents were employed. Nematodes were put in hot 70% alcohol; Cestodes and Trematodes in hot Bouin's fluid, 12–24 hours, and later placed in 70% alcohol. Leeches were also fixed in Bouin's, and Acanthocephala were placed in tap water whereupon their beaks extended, and then fixed in Bouin's.

Most of the worms were stained and mounted in toto, using para-carmine or borax carmine, and cedar oil for clearing. Some fish livers were sectioned to reveal smaller parasites, staining with Ehrlich's haematoxylin and eosin.

[1]The thesis was in partial fulfillment of the requirements for the degree Master of Science, University of Akron, 1941. Due to the entrance of Robert C. Hare into the U. S. Army, Dr. Walter C. Kraatz collaborated in the production of this paper.

The total number of fish examined for all worm parasites was 127, or 21 species, falling in 8 families. These are listed in the course of the paper. This is somewhat less than half of all the recorded fish species of the lakes. Of the 29 species not taken, 17 are minnows, 4 catfish, and 5 sucker species.

THE PARASITES, THEIR ABUNDANCE AND DISTRIBUTION IN RELATION TO HOSTS

Parasites found belong to Trematoda, Cestoda, Nematoda, Acanthocephala and Hirudinea.

Trematoda.—Ectoparasitic Trematodes, order Monogenea, were not represented. All those found were of Order Digenea, which require a snail as host for prior larval stages. There are two possible conditions: (1) those which attain maturity in the fish (then chiefly in the digestive tract), (2) those which are immature in the fish (metacercariae) to reach functional maturity only after being eaten by a fish-eating bird or mammal—or possibly some second predator fish or other aquatic vertebrate.

Allocreadium sp.—Three specimens were found in intestine of the common sunfish from shallow water over mud bottom in the Ohio Canal.

Microphallus Ward, 1901.—*Microphallus opacus* was found only in one rock bass, taken August 1 in shallow, weedy water of the Ohio Canal. About a dozen of the worms were present in stomach and intestine. Crayfish are said to carry the metacercaria in their liver (Ward, 1894). It may be significant that the rock bass host had a large crayfish in its stomach. Four of the nine specimens in the stomach were still metacercariae.

Strigeidae.—Those found were all of the larval group *Neascus*, well described by Hughes (1927). All occur in fish as encysted metacercariae.

Neascus vancleavii (Agersborg, 1926).—This parasite was found encysted in internal organs of various Centrarchidae, in moderate to heavy infestations. The common sunfish was very susceptible. The liver was infested with hundreds of the larvae. Most parasitized fish were from shallow water. The age of the fish seems to have bearing on Neascus infestation, at least in the bluegill. Of 14 of these under 4 inches from various localities in the lake, none were infested, but of the five larger bluegills, three were heavily infested. Some hybrids of common sunfish and bluegill were only lightly infested. Other hosts were the large-mouth black bass, warmouth bass.

Neascus amblopitis Hughes (1927).—This common parasite occurs as a deeply pigmented integumentary cyst, forming a slight elevation; often a fish appears literally peppered with them. All the infested fish were from shallow water. Heaviest infestations were found in perch, log perch, large-mouth bass; less in warmouth bass, long-eared sunfish and steel-colored minnow. Perch were seldom found without the cysts. Only young of the large-mouth bass were infested. Of ten bass under four inches from various parts of the lakes, nine were infested, whereas of nine over four inches, none were infested.

Cestoda.—Adults of fish tapeworms always occur in the alimentary canal of the fish. There is more flexibility of host species than in Trematodes, and also in host relations in larval stages. Larvae usually develop in Arthropods. In addition to serving as hosts for adult tapeworms, fishes frequently shelter advanced larvae which reach maturity in other fishes, amphibia, reptiles, birds or mammals.

Cestoda do not occur as abundantly as Trematoda or Acanthocephala in Portage Lakes fishes.

Proteocephalus, La Rue, 1914; *Proteocephalus amblopitis* (Leidy).—This is the most common species of cestode in Portage Lakes fishes. It was found in the digestive tract of all five of the garpike examined and in the stomach of the large-mouth bass. Larval forms were found in the liver, gonads and body cavity of the garpike and bluegills and in the pericardial cavity of the bass. These larvae have been known to cause economic loss because of infestation of gonads of hatchery bass. Bangham (1927) refers to it as "a most serious handicap to the hatching of bass."

Copepods have been shown (Hunter, 1928) to serve as first host for *P. amblo-plitis*. Van Cleave and Mueller (1934) state that Proteocephalus is of general distribution. Young fish seem less susceptible. All of the parasites were from mature fish.

Proteocephalus fluviatilis Bangham (1925).—Eight adults of this species were taken from one large-mouth black bass, caught May 23 in deep water in East Reservoir.

Proteocephalus singularis La Rue (1911).—This species, both as larvae and adults, occurred in the stomach of the long-nosed gar. In one instance over a hundred were taken from one host. All the fishes were from deep water.

Corallobothrium Fritsch; *Corallobothrium fimbriatum* Essex (1928).—Four worms of this species were found in the intestine of one mature black bullhead caught in January through the ice of Grape Lake.

Nematoda.—Roundworms were less frequently encountered than preceding group in Portage Lakes fishes.

Contracaecum Raillet and Henry.—The genus belongs to the Ascaroidea. *Contracaecum* sp.—Numerous larvae were encysted in the walls of the intestine and in mesenteries of two black bullheads caught January 1 through the ice of Grape Lake.

Philometra Costa.—The genus belongs to the order Filarioidea. *Philometra cylindracea* Ward and Magath (1917)—A single adult female of this roundworm was taken from the intestine of a rock bass August 1, from the shallow water of the Ohio Canal.

Acanthocephala.—Thorny-headed worms were found to be the most abundant worm parasites of fishes in this study, although only three species of these parasites were found.

Neoechinorhynchus Hamann; *Neoechinorhynchus cylindratus* (Van Cleave, 1913).—This worm occurred in great abundance in the large-mouth black bass, crowding the intestine. It was found in both young and old fish, the severity of the infestation increasing with age. Although many different hosts are given for this species by various workers, in this study it was not found outside of the bass, except for one instance of larvae encysted in liver of a common sunfish.

Leptorhynchoides thecatus (Linton, 1891).—This parasite was the most abundant of the Acanthocephala, and of all the worm parasites of Portage Lakes fishes. It was widely distributed in fish species, commonest in large-mouth black bass; bluegill; next commonest in hybrid sunfish, common sunfish, warmouth bass, and found also in other Centrarchidae and occasionally in other fishes. It occurred in stomach and intestine, sometimes so numerous in a host as to clog the intestine and tear the walls, and sometimes found in the coelom. Older hosts were more heavily infested.

In life cycle studies, Van Cleave (1920) showed that larvae lived in the Amphipod *Hyalella knickerbockeri*. This amphipod is also abundant in the Portage Lakes. It appears that larvae from these arthropod hosts swallowed by the fish may, presumably if too small, bore through the fish intestine wall and proceed with larval growth in a cyst within the viscera. Such encysted larval stages were found in various internal organs. Thus a fish may become an additional intermediate host.

Pomphorhynchus Monticelli; *Pomphorhynchus bulbocolli* Linkins.—This species was less abundant than the other two species but rather widely distributed. It was found chiefly in the goldfish and black bullhead, but also in yellow perch, long-eared sunfish, warmouth bass. It was in the intestine, except also in gonads in goldfish.

The Acanthocephala are so abundant in most hosts as to cause serious damage. This has been discussed by Bangham (1928), Van Cleave (1919), and Pearse (1924). The damage to fishes in the present collections was often evident. When the intestinal lumen was clogged, laceration of walls with holes was frequent, resulting in inflammation and yellowing of the tissues.

Acanthocephala seem to be well adjusted to their parasitic existence. There is no free-living stage. Two hosts are always required. Larval hosts are Insects or Crustacea. (Van Cleave and Mueller, 1934). Since host-parasite relationship is not very specific, adults may be in many species of fishes, passing from one to another as a predator eats a small fish. A large predator might adopt the Acanthocephala of several host victims. This was shown in this study of the Centrarchidae of the Portage Lakes. All the Centrarchidae showed high percentage of infestation, except the white crappie. Practically every specimen of the others was infested heavily. In six white crappie no Acanthocephala were found. The identifiable stomach contents of the white crappie (six specimens) were the fry of gizzard shad, *Dorosoma cepedianum*, which is a fish now well known to feed almost exclusively on phytoplankton (Tiffany, 1921), and sometimes on bottom mud. This parasitically sterile fish, when serving as the food of white crappie, explains the nearly complete lack of parasitism of the crappie in the present instance.

Seasonal periodicity of Acanthocephala infestation was also noted. Winter fish collections were almost devoid of these worms of adult stage. The hosts feed little in the winter. Acanthocephala may overwinter more as larval forms.

Hirudinea.—Leeches are of relatively minor importance as fish parasites. A total of only four leeches were found on fish taken in this study. One of these was a leech of genus *Illinobdella*, from the skin of a warmouth bass, caught through the ice in February in Grape Lake, which is very shallow. The other three were not identified and were found on gills of black bullhead, and the roof of the mouth of a long-eared sunfish from the Ohio Canal, and the other from the fin of a bluegill from North Reservoir. There was no correlation between infestation and season or habitat type.

CORRELATION OF PARASITISM AND HABITAT

Because of the small areas involved, the differentiated habitats are not extensive, so that many fish may not be so fully restricted to one habitat. But they have their individual environment preferences. Some parasites also appear to have such restricted habitats, which is probably determined chiefly by the range of the intermediate hosts.

Parasitism occurs more in shallow than deep water; 28% of the fish taken in deep, open water were parasitized, but 73% of the fish taken in shallow water were infested. Of shallow water fish, 27% were infested with Trematodes, but only 4% from deep water had Trematodes. However, Cestodes were found in 44% of deep water fish and only 3% of shallow water fish, and thus in contrast to the other parasites.

Acanthocephala were predominately in the shallow water association, 56% of fish in shallow water as contrasted to 32% in deep water were infested. The fish taken from a hard bottom habitat were 95% infested with Acanthocephala; those taken from a soft bottom habitat were 44% infested.

In fact, hard-bottom, shallow-water habitat fish had the greatest infestation throughout, double that of the shallow-water, mud-bottom habitat fish and not quite double that of the deep-water, mud-bottom habitat fish, in latter of which tapeworms raised the percentage of infestation. Probably the explanation is largely that the carnivorous fish like Centrarchidae were mostly taken in the hard-bottom shallow water.

TABLE I

PERCENTAGE OF PARASITISM IN FISH FAMILIES AND SPECIES

Family of Fishes	Number Examined		Percent Infested	
Species and Common Name	Fam.	Sp.	Fam.	Sp.
Lepisosteidae	5		100	
Lepisosteus osseus, long-nosed garpike		5		100
Clupeidae	7		0	
Dorosoma cepedianum, gizzard shad		7		0
Cyprinidae	16		18.7	
Cyprinus carpio, carp		1		100
Carassius auratus, goldfish		1		100
Notropis whipplii, steel-colored minnow		1		100
Notemigonus crysoleucas, golden shiner		6		0
Hyborhynchus notatus, blunt-nosed minnow		7		0
Ameiuridae	5		80	
Ameiurus melas, black bullhead		5		80
Esocidae	1		100	
Esox vermiculatus, grass pike		1		100
Percidae	11		36.4	
Perca flavescens, yellow perch		3		66.6
Percina caprodes, log perch		8		37.5
Centrarchidae	66		89.7	
Huro salmoides, large-mouth black bass		19		100
Lepomis macrochiarus, bluegill		19		94.7
Eupomotis gibbosus, common sunfish		8		100
L. machrochiarus x *E. gibbosus*, hybrid sunfish		4		100
Ambloplitis rupestris, rock bass		1		100
Chaenobryttus gulosus, warmouth bass		7		71.4
Pomoxis annulairs, white crappie		6		16.6
Pomoxis sparoides, black crappie		1		100
Xenotis megalotis, long-eared sunfish		1		100
Atherinidae	16		0	
Labidesthes sicculus, brook silversides		16		0

AMOUNT OF PARASITISM IN THE FISHES

From the ecological point of view one is interested in the species of parasites a host harbors, the relative abundance of the parasite species, and also in the percentage of host specimens infested. Kinds of parasites and relative abundance have been presented above, together with relations of fish species. There is no room for detailed data for every fish examined, but a list of fishes, grouped by families, is given here (Table I), showing percentage of infestation of the fish species.

DEGREE OF PARASITISM WITHIN THE FISH FAMILIES CORRELATED WITH FEEDING HABITS

Of the total fish taken, 127, the number infested with one or more kinds of worm parasites was 76, or a percentage of 59.8, which by coincidence at least is practically the same as the 58.3% on a much larger number of Lake Erie fish, 2,156, found by Bangham and Hunter (1939). Essex and Hunter, 1926, working in the Central States, obtained a 39% infestation in 652 fish examined.

The number of fish examined is admittedly very small, especially for some species, but it seems that the data should give some idea of the fish parasite relation of many of the fish types of these inland lakes.

Consideration of the fishes by families is of some significance and allows for some generalization. It is not that phylogenetic relationship is of dominant importance, but food habits naturally are important in the matter of securing parasite infection and thus important for all fishes of a family having similar food habits. Where there is a striking exception, it can be seen that the difference in food accounts for the difference in parasites. Such is the case in the white crappie, utterly free of Acanthocephalan parasites, whereas all other Centrarchidae were heavily infested. (The percentage in the table for white crappie is due to a very light infestation of one of the six with a different but unidentified parasite.)

The families with high percentage of infestation are Lepisosteidae (100%), Ameiuridae (80%), Esocidae (100%), and Centrarchidae (89.7%).

The data on food of every fish taken was kept, but space limitation prevents inclusion here.

The records on Lepisosteidae and Esocidae are based on meagre catches here, but their food habits are well known. Ameuridae may have more versatile food habits, but the five black bullheads contained chironomid larvae and snails only. The food of all the 66 members of Centrarchidae was comprised of fish, crayfish, snails, chironomids and other insects, and some Cyclops and Cladocera in some young specimens. They were predominantly carnivorous.

These families included the so-called game fishes and similar forms.

One family, Percieae, more intermediate in degree of parasitism, comprises fish of versatile food habits.

The three families least parasitized were Clupeidae (0%), Cyprinidae (18.7%), and Atherinidae (0%). These are definitely non-game fishes.

The gizzard shad of the Clupeidae (already referred to) feeds largely on phytoplankton and may take some mud. The Atherinidae feed primarily on plankton, (Sibley, 1929). Many of the Cyprinidae are known to be bottom feeders and scavengers and to a large extent feed also on plankton. For example, the bluntnosed minnow is typical as well as versatile, as shown in a food study from these same waters, (Kraatz, 1928).

It is clear that those fishes whose main diet is plankton and especially those feeding on phytoplankton, and bottom materials, show no parasitism or low degree of parasitism.

CORRELATION OF PARASITISM WITH AGE OF HOST

The parasitic fauna often changes markedly with age, a consequence of changing food habits. Most fish feed on minute Crustacea and other plankton when young, thus acquiring those parasites which utilize some of the smaller Arthropods as hosts, such as the Acanthocephala. As the fish grows older, if carnivorous, it begins to capture larger animal forms and then becomes exposed to other parasitic worms, such as trematodes and cestodes. Data are here presented for the bluegill and large-mouth black bass. The Acanthocephalan ***Leptorhynchoides thecatus*** is found in both the young and mature bluegill and bass. The cestodes and trematodes occur only in the more mature bluegills. In the large-mouth bass, however, *Neascus amblophitis* appears primarily as a parasite of the immature fish, although the cestode *Proteocephalus amblophitis* is found only in the older fish. Because of their larger size and more voracious appetite the large-mouth bass might be infested by trematodes while still relatively young.

TABLE II

EFFECT OF AGE ON PARASITISM

Figures show percent of fish infested

Parasite	Bluegill		Largemouth Bass	
	Under 4″	Over 4″	Under 6″	Over 6″
L. thecatus	91	88	77	100
P. amblophitis	0	25	0	50
N. vancleavii	0	25	8	17
N. amblophitis	0	17	69	0

SUMMARY

A total of 127 fish, representing 21 species of 8 families, were taken from the Portage Lakes.

Parasites were studied. Most were endoparasites, a few leeches being the only ectoparasites. The classes Trematoda, Cestoda, Nematoda, Acanthocephala were represented; the Nematoda least of these.

Acanthocephala, with *Leptorhynchoides thecatus* in intestine, strikingly abundant, were the most common and widespread parasites. *Neoechinorhynchus cylindratus* was second in abundance of thorny-headed worms.

The trematode, occurring as metacercariae, *Neascus vancleavii* was also often abundant in liver and *Neascus amblophitis* as a skin encysted parasite.

Shallow water fish exhibit a higher degree of parasitism than deep water fish and those from a hard bottom more infested than those of a mud bottom. But Cestodes were commoner in deep water fish.

Food habits have a marked relationship with parasitism. Families Clupeidae, Atherinidae and Cyprinidae, which are more herbivorous and bottom and general feeders, had a collective percentage of parasitism of only 7.7%.

The five other families, Lepisosteidae, Ameiruidae, Esocidae, Percidae, and Centrarchidae, showed a collective infestation of 83.5%. These are chiefly carnivorous, and many of them game fishes. The Percidae were least infested of these five, and they are less carnivorous than the other four families.

There is some correlation of parasitism with age of host, parasitic fauna changing with the changing food habits of the growing fish.

Of the 127 fish, 76 or 59.8% harbored one or more species of worm parasites.

LITERATURE CITED

Agersborg, B. P. K. 1926. Studies on the affect of parasitism upon the tissues. II. With special reference to a new Diplostomous trematode found in the minnow *Notropis anogenus* Forbes. Arch. f. Schiffs-u. Tropen-hyg., 30: 18–30.

Bangham, R. V. 1925. A study of the cestode parasites of the black bass in Ohio, with special reference to their life history and distribution. Ohio Jour. Sci., 25: 255–262.

1927. The life history of cestode *Proteocephalus amblophitis*. Trans. Amer. Fish Soc., 47: 206–208.

1928. Parasites of black bass. Sci., No. 27: 267–270.

1928a. Distribution of parasites of black bass in lakes and streams of Ohio. Ohio Cons. Bull., 17.

Bangham, R. V., and **Hunter, G. W., III.** 1939. Studies of fish parasites of Lake Erie. Distribution studies. Zoologica, 24: 385–448.
Essex, H. E. 1928. The structure and development of Corallobothrium with descriptions of two new fish tapworms. III. Biol. Monogr., II (3): 1–75.
Essex, H. E., and **Hunter, G. W., III.** 1926. A biological study of fish parasites from the Central States. Trans. Ill. Acad. Sci.
Hare, Robert C. 1941. An ecological study of the worm parasites of Portage Lakes Fishes. (Unpublished thesis, University of Akron.)
Hughes, R. C. 1927. Studies on the trematode family Strigeidae (Holostomidae) VI. A new Metacercaria Neascus amboplitis, sp. nov., representing a new larval group. Trans. Amer. Micros. Soc., 46: 248–267.
Hunter, G. W., III. 1928. Contributions to the life history of *Proetocephalus amboplitis* (Leidy). Jour. Parasitol., 16: 229–242.
Kraatz, W. C. 1928. Study of the food of the blunt-nosed minnow, *Pimephales notatus.* Ohio Jour. Sci., 28: 2: 86–98.
1931. A quantitative net-plankton survey of East and West Reservoirs, near Akron, Ohio. Ohio Jour. Sci., 31: 6: 475–500.
1941. Quantitative Plankton studies of Turkeyfoot Lake, near Akron, Ohio. Ohio Jour. Sci., 41: 1: 1–22.
La Rue, G. R. 1914. A revision of the cestode family Proteocephalidae. III. Biol. Monogr., 1: 1–350.
Linton, R. 1891. A contribution to the life cycle of *Dibothrium cordiceps*, a parasite infesting the trout of Yellowstone Lake. Bull. U. S. Fish Comm., 9: 337–358.
Osburn, R. C. 1921. Report on the fish conditions in the Portage Lakes. Ohio Sportsmens Bull. I.
Pearse, A. S. 1924. Observations on parasitic worms from Wisconsin fishes. Trans. Wis. Acad. Sci., Arts, Letters, 21: 147–160.
Sibley, C. K. 1929. The food of certain fishes of the Lake Erie drainage basin. Suppl. 18th Ann. Rept. N. Y. State Cons. Dept., 1928: 180–188.
Tiffany, L. H. 1921. Algal food of the young gizzard shad. Ohio Jour. of Sci., 21: 113–122.
Van Cleave, H. J. 1913. The genus Neoechinorhynchus in North America. Zool. Anz., 43: 177–190.
1919. Acanthocephala from the Illinois River, with descriptions of species and a synopsis of the family Neoechinorhynchidae. Bull. Ill. Nat. Hist. Surv., 13: 222–257.
1920. Notes on the life cycle of two species of Acanthocephala from fresh-water fishes. Jour. Parasitol., 6: 167–172.
Van Cleave, H. J., and **Mueller, J. F.** 1934. Parasites of Oneida Lake fishes. Part III. A biological survey of the worm parasites. Roosevelt Wild Life Annals, 7: 159–335.
Ward, H. B. 1894. Some notes on the biological relations of the fish parasites of the Great Lakes. Proc. Neb. Acad. Sci., 4: 8–11.
1901. Notes on the parasites of lake fish. III. On the structure of the copulatory organs in Microphallus nov. gen. Trans. Amer. Mic. Soc., 22: 175–187.
Ward, H. B., and **Magath, T. B.** 1917. Notes on some nematodes from fresh-water fishes. Jour. Parasitol., 3: 57–64.